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Experimental Confirmation of CH Mandrel Removal from Be Shells

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From: Bob Cook, Steve Letts, and Steve Buckley

Subject: Experimental confirmation of CH mandrel removal from Be shells

Summary:

We have demonstrated plastic mandrel removal from sputtered Be shells through a 6 µm diameter fill hole by forcing air at 450 °C in and out of the shell by varying the external pressure.

Introduction

Sputtered Be shells are made by sputter deposition of Be, with a radially graded Cu dopant as necessary, onto plastic mandrels supplied by General Atomics. Although the plastic mandrel may not be a design issue, it is a fielding issue because at cryo temperatures the plastic shrinks more than the Be and delaminates. We described in previous memos[1,2] a proposed method for thermally removing the plastic by burning it in air at elevated temperature. A key aspect to this process is getting air in and out of the shell through the small diameter hole that must be laser drilled in the capsule wall to serve as a fill hole for the fuel. Because the hole is quite small, gas flow through the orifice must be forced, and an external pressure variation was suggested to do this. Further calculations showed that since the volume of the capsule is quite small and the amount of plastic in the shell by comparison is large, the "pumping" of air in and out of the shell must occur at least once per minute in order to supply enough O_2 to completely burn the plastic to CO_2 and H_2O in a reasonable time. Such an apparatus has been now built and this memo details both its construction and operation, as well as provides the first evidence of plastic mandrel removal from Be shells.

Apparatus

The description below is for the current device, as will be noted in the results section there was an earlier model that had problems.

The heat exchanger is simply an extended stainless steel tube that sits in a clam shell furnace as shown in Figure 1. The extended steel tube provides a source of hot air to the capsule, which sits in a cavity in the metal fitting shown. The pressure in the tube is regulated (off to the left) by a solenoid valve that raises the pressure to 60 psi in 2 seconds, holds it there for 30 sec, then bleeds it down to 20 psi over 30 sec before

[1] Bob Cook, "Mandrel Burn-Out in Be Shells," October 23, 2003. Copy available from the author.
[2] Bob Cook, "Mandrel Burn-Out in Be Shells - Gas Flows," March 9, 2004. Copy available from the author.

repeating. These pressures are in excess of the ambient 15 psi, thus the pressure the shell sees varies between about 5 and 2 atm. Although the pressure in the tube follows this variation closely, the pressure (and thus the amount of O_2) in the shell lags and depends upon the rate of gas flow through the drilled hole.[2] For the experiments thus far performed the diameter of the hole has been at the smallest 5-6 µm, and the length of these holes (Be wall thickness) about 20 µm. Smaller diameter and longer holes will certainly restrict flow further, however calculations[2] show that it is still possible to get sufficient gas in and out of the shell to effect complete decomposition.

Figure 1. Photo of heat exchanger

Results.

Before proceeding to the successful work, it is worth seeing the results of the first experiments since they provide a good view of the process. The initial shell tested had a large hole laser drilled in it so that gas exchange would not be an issue. A photo of the hole, roughly 30 µm long, is shown in Figure 2a. In Figure 2b is shown a radiograph of a portion of the wall of this capsule before heating. The plastic mandrel and Be wall can be seen clearly. In the initial apparatus heat transfer was a problem and the capsule did not get as hot as we thought. Thus when the shell was radiographed after heating for about 35 h the mandrel was not gone as the radiographic image shows in Figure 3a. Here we can clearly see the shrunken mandrel, which had lost about 70 out of 170 µg of its mass. At this point it was clear that the temperature control was inadequate and the current design was adopted. In Figure 3b we show a radiograph of the capsule after 16 more hours of heating at 400 °C, only a small fragment of the mandrel is still visible. The shell was then heated for 23 hours at 450 °C, which completely removed the remnants of the mandrel as shown in Figure 3c. It should be noted that for each of these last two heating periods the pressure was varied as described above.

Having worked out the heating transfer problem, we now tried a shell with a small hole, about 5-6 µm as shown in Figure 4a. In radiograph (Figure 4b) a portion of the shell wall is shown, clearly indicating the plastic mandrel and an outer Be layer that is about 18 µm thick. The shell was placed in the furnace at 450 °C for 35 hours with 1 pressure cycle per minute. The resulting shell radiograph showing complete mandrel removal is displayed in Figure 4c. A second shell with a similar hole was subjected to the same treatment with the same result.

In order to carefully check the inside, a shell was broken open. There appeared to be very small black flecks of film adhering to the inside of the Be. A SEM picture is shown in Figure 5. At this point we do not know the composition or source of these flecks, but they will be a focus of our development of this process.

The degree of oxidation of the Be in the shells due to the heating process will also be explored. One quick comparison has been made by measuring the XRF signal for oxygen on the outside of a shell before and after heating. There was roughly a factor of 3 increase.

We will also explore the gas transport issues with longer and smaller holes when the current batch of shells come out of the coater with an excess of 100 µm walls.

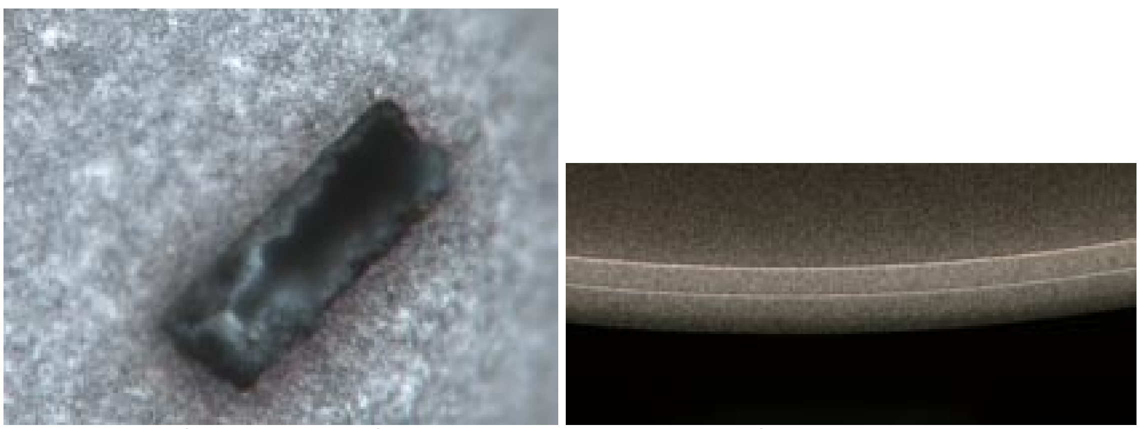

Figure 2. Left, an image of the big hole drilled in the first capsule tested. Right, a radiographic image of a portion of the shell wall before heating, clearly showing the outer Be and inner plastic layers.

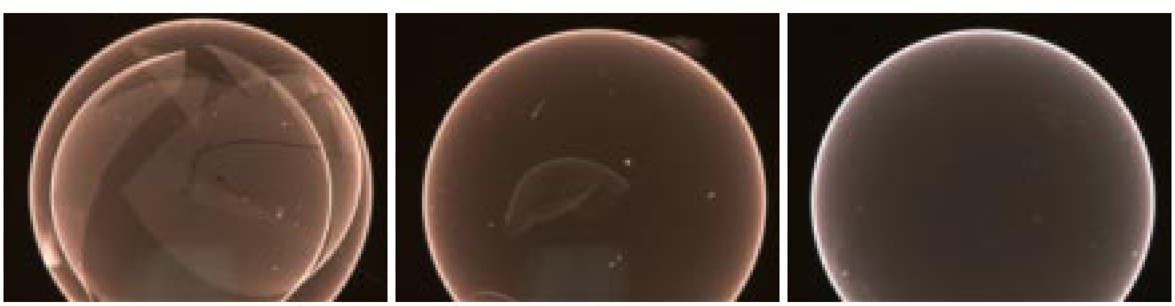

Figure 3. Right, the first shell after 35 h of heating at an unknown low temperature before we had developed the device shown in Figure 1. Center, the same shell after 16 more hours of heating at 400 °C in the new device with pressure cycling of once per minute. Right, after 23 more hours of heating at 450 °C.

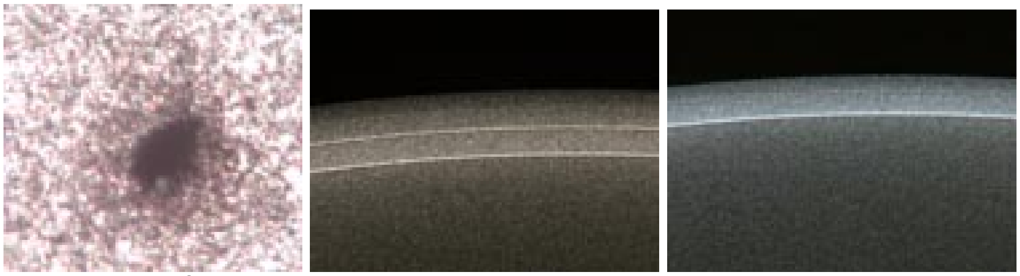

Figure 4. Left, a roughly 6 μm diameter hole in the second shell tested. Center, before heating, right after 35 h at 450 °C with one pressure cycle per minute.

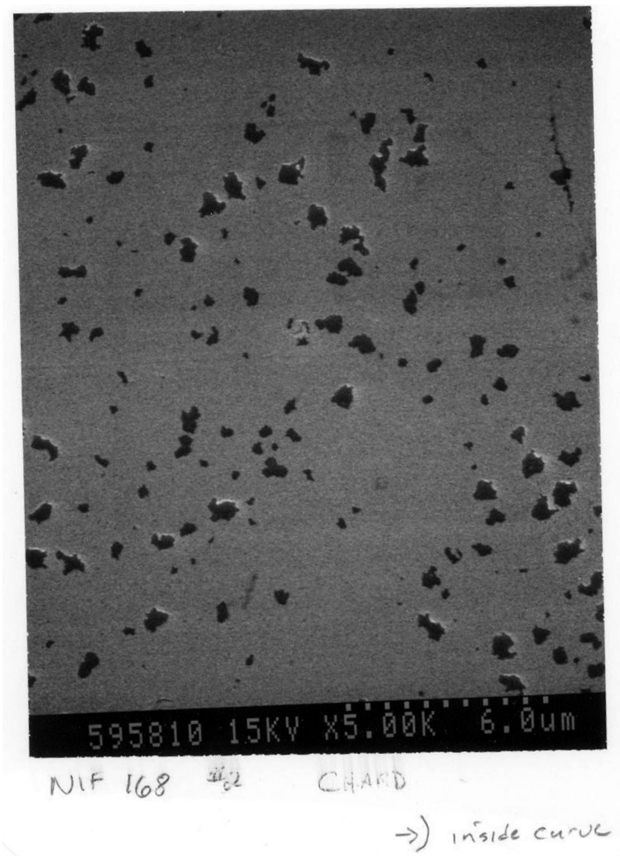

Figure 5. SEM of black specks left inside of shell.